Using Simulation to Optimize Ski Jump Ramp Profiles for STOVL Aircraft

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Introduction
Ramps have been used for many years aboard the Navy ships of many countries to reduce takeoff run distance and wind-over-deck (WOD) requirements, as well as to increase the aircraft takeoff gross weight capability over that of a flat deck carrier. Under the Joint Strike Fighter program, an effort has been funded to evaluate various ramp profiles and ramp performance optimization methodologies. Results of these evaluations will be used with an advanced STOVL aircraft to provide the maximum benefit to takeoff performance, while not becoming a design driver for landing gear or adversely affecting ship designs.

The Boeing AV-8B Harrier is a true STOVL aircraft, in that it routinely performs short takeoffs and vertical landings. This allows operations from ships not equipped with catapults or arresting gear and that are considerably smaller than the US large deck carriers. This unique capability is obtained through a group of variable angle nozzles for vectored lift and a reaction control system for stability and control, which uses engine bleed air to provide thrust through several small nozzles located on the aircraft.

Many foreign navies operate Harriers from ships equipped with smooth profile ramps. The US Navy has conducted many ship and shore-based tests of smooth and segmented (flat plate) ramp profiles over the years to demonstrate the performance advantages of a ramp-assisted takeoff. Much of this work serves as the basis for our research initiative.

Preliminary Work
The first step was to collect data from prior flight tests to validate the AV-8B landing gear model. The test data were incomplete because the test aircraft did not have sufficient instrumentation to measure gear/store loads and accelerations. Therefore, criteria were developed which enabled us to compare predicted gear load trends and instead of actual gear and structural loads.

Preliminary Criteria for Ramp Optimization

1. The landing gear shall not compress to full closure at any point during the takeoff. Harrier flight tests have been conducted to within ½ inch of full closure with no adverse results.
2. Investigate a segmented ramp versus a smooth profile ramp, and how it could be used with the existing structural and operational requirements of the aircraft. If so, what is the maximum angle change between segments that can be tolerated by the aircraft and aircrew?
3. Resonance effects from segmented ramps on landing gear and wing mounted stores are unknown, and efforts should be taken to break up or reduce these loads.

Preliminary Results
Preliminary simulation runs have been completed. Test results indicate that the segmented ramp concept shows great promise and could allow ship designers options in building retractable or reconfigurable ramp designs for future STOVL capable ships. Segmented ramp takeoff performance is not diminished as compared with a smooth ramp. Initial results indicate that segmented ramp profiles can be modified to keep the gear loads well within their structural limits. Since the velocity of the aircraft remains fairly constant while it is on the ramp, an equally distributed (same length) segment pattern generates a recurring load on the landing gear at each joint. If the frequency of these inputs is close to the natural frequency of the gear, or transmitted through the aircraft structure to a wing store, a resonance condition could be excited. This will be investigated at in more detail in the coming months.

Preliminary Conclusions
The smooth and segmented ramp profiles have demonstrated significant performance gains over a field or flat deck ship takeoff. Work will continue over the next several months to expand and refine the optimization criteria and investigate various ramp profiles and quantify their benefit to aircraft performance.

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